UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

July 24, 2024

Adam C. Heflin
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SUBJECT: PALO VERDE NUCLEAR GENERATING STATION, UNITS 1, 2, AND 3 – PRESSURIZER SURGE LINE INSPECTION PROGRAM (EPID L-2023-LRO-0052)

Dear Adam Heflin:

By letter dated July 26, 2023, as supplemented by letters dated January 12, 2024, and May 14, 2024), Arizona Public Service Company (the licensee) requested approval for the Pressurizer Surge Line Inspection Program to manage the aging effect of environmentally assisted fatigue (EAF) in the pressurizer surge line at Palo Verde Nuclear Generating Station (Palo Verde), Units 1, 2 and 3.

The licensee's submittal of the proposed program and associated flaw tolerance evaluation is related to the commitment described in the safety evaluation report in NUREG-1961, "Safety Evaluation Report Related to the License Renewal of Palo Verde Nuclear Generating Station, Units 1, 2, and 3," April 2011; section 4.3.1.5.2, on the Palo Verde license renewal for the period of extended operation, which is 40 to 60 years of operation. Specifically, the licensee's submittal is related to the commitment to perform a flaw tolerance evaluation, impose component-specific inspections, and obtain approval from the regulatory agency. Accordingly, the licensee submitted its flaw tolerance evaluation and Pressurizer Surge Line Inspection Program for U.S. Nuclear Regulatory Commission (NRC) staff's review and approval.

As described in the enclosed safety evaluation, the NRC staff determined that the licensee-proposed Pressurizer Surge Line Inspection Program and the associated flaw tolerance evaluation are acceptable to manage cracking due to EAF for the pressurizer surge line at Palo Verde, Units 1, 2 and 3, by using the periodic inspections (once per 10 years) for the period of extended operation. Therefore, the NRC staff approves the use of the proposed Pressurizer Surge Line Inspection Program for the period of extended operation.

If you have any questions, please contact me at (301) 415-3329 or via email at William.Orders@nrc.gov.

Sincerely,

Jennivine K. Rankin

Digitally signed by Jennivine K. Rankin
Date: 2024.07.24 12:29:10 -04'00'

Jennivine K. Rankin, Project Manager
Plant Licensing Branch IV
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. STN 50-528, STN 50-529,
and STN 50-530

Enclosure:
Safety Evaluation

cc: Listserv

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

REQUEST FOR ACCEPTANCE OF

THE PRESSURIZER SURGE LINE INSPECTION PROGRAM

PALO VERDE NUCLEAR GENERATING STATION UNITS 1, 2, AND 3

DOCKET NOS. STN 50-528, STN 50-529 and STN 50-530

1.0 INTRODUCTION

By letter dated July 26, 2023 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML23207A248), as supplemented by letters dated January 12, 2024, and May 14, 2024 (ML24012A245 and ML24135A248, respectively), Arizona Public Service Company (APS, the licensee) requested approval for the Pressurizer Surge Line Inspection Program to manage the aging effect of environmentally assisted fatigue in the pressurizer surge line at Palo Verde Nuclear Generating Station (Palo Verde), Units 1, 2 and 3. The Pressurizer Surge Line Inspection Program is based on a flaw tolerance evaluation in accordance with American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Section XI, nonmandatory appendix L, “Operating Plant Fatigue Assessment.” The program includes periodic inspections for aging management.

The licensee’s submittal of the proposed program and associated flaw tolerance evaluation is related to the commitment described in the safety evaluation report in NUREG-1961, “Safety Evaluation Report Related to the License Renewal of Palo Verde Nuclear Generating Station, Units 1, 2, and 3”; section 4.3.1.5.2, on the Palo Verde license renewal for the period of extended operation, which is 40 to 60 years of operation (ML11095A011). Specifically, the licensee’s submittal is related to the commitment to perform a flaw tolerance evaluation, impose component-specific inspections, and obtain approval from the regulatory agency. Accordingly, the licensee submitted its flaw tolerance evaluation and Pressurizer Surge Line Inspection Program for U.S. Nuclear Regulatory Commission (NRC) staff’s review and approval.

2.0 REGULATORY BASIS

Pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) 54.21, “Contents of application – technical information,” each application for license renewal must contain an integrated plant assessment (IPA) and an evaluation of time limited aging analyses. The plant-specific IPA shall identify and list those structures and components subject to an aging management review and demonstrate that the effects of aging will be adequately managed so that their intended functions will be maintained consistent with the current licensing basis for the period of extended operation as required by 10 CFR 54.21(a)(3). Specifically, the regulations in

10 CFR 54.21(c)(1)(iii) state, “The effects of aging on the intended function(s) will be adequately managed for the period of extended operation.”

The licensee proposed the Pressurizer Surge Line Inspection Program to manage the aging effect of EAF in the pressurizer surge line at Palo Verde, Units 1, 2, and 3. The aging management inspection program is based on a flaw tolerance evaluation in accordance with the ASME Code Section XI, nonmandatory appendix L.

3.0 NRC STAFF EVALUATION

3.1 Flaw Tolerance Evaluation

APS manages the aging effects of EAF on the pressurizer surge line using periodic inspections at a frequency determined by a flaw tolerance evaluation in accordance with ASME Code, 2013 Edition, Section XI, nonmandatory appendix L, “Operating Plant Fatigue Assessment.” The proposed pressurizer surge line inspections based on flaw tolerance approach has been approved by NRC staff and has been implemented and used successfully for managing fatigue for extended plant operation for several pressurizer water reactors (Turkey Point Nuclear Generating Unit Nos. 3 and 4; St. Lucie Plant, Unit Nos. 1 and 2; Arkansas Nuclear One, Unit 2).

The NRC staff reviewed the licensee’s submittal that includes the proposed method to manage EAF or the pressurizer surge line and the flaw tolerance evaluation of the Palo Verde, Units 1, 2, and 3 surge line piping using ASME Code Section XI, appendix L.

The licensee states that all butt weld locations on the surge line, excluding the pressurizer and hot leg surge nozzles that have been weld overlaid on all three units, are evaluated and the pressurizer and hot leg surge nozzle weld overlays are addressed separately. The NRC staff acknowledges that those overlays of pressurizer surge nozzles will be managed by the Alloy 600 Management Program and are not evaluated here.

The licensee states that the assessment of EAF for the surge line piping components has identified that a location on the hot leg elbow body has the highest fatigue usage. The licensee conducted a flaw tolerance evaluation for elbows and concluded that it will take significantly longer for the postulated flaw to grow to the allowable size in an elbow as compared to the butt weld location. Thus, the butt weld analyses will set the examination interval. The NRC staff reviewed the evaluation of the elbow and finds this conclusion is acceptable.

The NRC staff reviewed the principal tasks of the fatigue crack growth analysis. These are: (1) to determine the loads and stresses at the critical locations in the surge line (including all butt welds); (2) to determine the allowable flaw depths for various service levels; (3) to postulate hypothetical flaws at the locations for both axial and circumferential flaws in accordance with the ASME Code Section XI, appendix L; (4) to use the stresses and crack flaw model to calculate stress intensity factors and predict fatigue crack growth (FCG) to determine the end-of-period flaw size; and (5) to determine the time necessary for postulated initial flaw to grow to the allowable flaw depth. The staff’s assessment is as follows:

3.1.1 Determine the Loads and Stresses at the Critical Locations in the Surge Line

The licensee performed stress analyses for transients, mechanical piping loads, and internal pressure. The entire surge line piping system is modeled using 3D Finite Element Analysis

(FEA), which will automatically account for piping interface loads induced by thermal expansion during thermal stratification. APS evaluated mechanical loads accounting for deadweight, thermal expansion, thermal anchor movements, and seismic loads. The pressure and mechanical load analyses were performed by applying a unit pressure/load (1000 pounds per square inch (psi)/1000 pounds (lb.)) in the 3-dimensional model and scaling the stress results as needed based on the actual piping loads in the subsequent analyses. Two thermal load cases (thermal transient and thermal stratification) are used for the selection of the critical stress paths. The NRC staff reviewed the licensee's evaluation of the loads and stresses calculation and concludes that the bounding stress paths selected by the licensee are acceptable.

3.1.2 Determine the Transients Projected Cycles and Cycle Rate

The NRC staff reviewed the transients that will be considered in the subsequent FCG evaluation. The licensee listed the entire collection of design transients used for Palo Verde, Units 1, 2, and 3. The monitored cycles for each Palo Verde unit are established using SI:FatiguePro software to determine the total number of cycles that have occurred to-date for each counted plant transient. The licensee used the monitoring cycle counts to determine the expected total number of occurrences at 60 years. This was done for all transients except plant loading and plant unloading, for which the licensee assumed that the full design number of cycles will be spread uniformly over the licensed plant operating period. The staff finds this approach is reasonable for projecting the number of transients.

3.1.3 Determine the Allowable Flaw Size

The allowable flaw sizes are used in conjunction with an FCG evaluation to demonstrate that a postulated flaw will not grow sufficiently to exceed the allowable flaw size before the next scheduled inspection. Guidance for calculation of allowable flaw sizes is provided by ASME Code Section XI, appendix L (L-3000). Appendix L-3330 states that the allowable flaw size (circumferential and axial depth/length) for the welds will be determined based on the rule in ASME Code Section XI, subsection IWB-3640 and appendix C. The NRC staff reviewed APS allowable flaw sizes calculation and finds the allowable flaw sizes are calculated in accordance with ASME Code Section XI. Therefore, the staff finds the calculated allowable flaw sizes are acceptable.

3.1.4 Fatigue Crack Growth Calculation

The FCG analyses for the postulated flaws including hypothetical flaws at critical locations both axial and circumferential, were performed in accordance with ASME Code Section XI, Appendix L to determine the required inspection interval. The reference FCG rate curves were from ASME Code Case N-809, "Reference Fatigue Crack Growth Rate Curves for Austenitic Stainless Steels in Pressurized Reactor Water Environments, Section XI, Division 1," for Type 304/316 stainless steels and associated weld metals in a pressurized-water reactor (PWR) environment. The analyses use Paris' Law, which determines crack growth, in part, as a function of stress intensity, number of cycles, and factors that account for metal temperature. The NRC staff asked the licensee for clarification on these three factors, as discussed below.

The NRC staff asked the licensee to clarify the method in determining stress intensity factors K_{max} and K_{min}. By letter dated January 12, 2024, the licensee responded that for the crack growth analysis, the K_{max} thermal transient and K_{max} pressure (and similarly K_{min} thermal transient and K_{min} pressure) values were extracted from the transient runs and added together to represent the transient loading block of the event. This approach is conservative because the

peak K values of pressure and thermal transient loading are calculated separately and then combined, which excludes any reduction in K values at a specific time point due to out-of-phasing. On the basis that this approach is conservative, the staff finds the method acceptable.

The NRC staff identified that the licensee was using fractional cycles for the transients, whereas Paris' law is based on the number of complete cycles. In response to the staff's questions, by letter dated January 12, 2024, the licensee stated that in the equation for determining the crack growth, the term for the number of cycles need not necessarily be an integer. A cycle can be divided into several parts and the crack growth analysis be performed accordingly. In this case, the stress intensity factor is updated for each cycle, per number of divisions of the cycle. The use of fractional cycles results in the same final crack growth or produces conservative results. The licensee provided examples to demonstrate the conservatism. Based on the conservative FCG results, the staff finds it acceptable to use fractions of cycles to evaluate the crack growth.

The NRC staff also identified that the licensee used the average temperature of the transient to determine the crack growth. This yields a low crack growth rate when using Code Case N-809 methods. The staff noted that using the average temperature results in a crack growth rate that is non-conservative over the majority of the transient, and that is up to a factor of 4 lower than if the maximum or minimum temperature is assumed. The staff asked the licensee to demonstrate that using average temperature to perform FCG is adequate. The licensee reperformed the FCG analysis at the limiting locations using the maximum transient temperatures. The results showed that the minimum time for the crack to grow to the allowable size is 13 years, which bounds the 10-year inspection period. On the basis of the evaluation using maximum transient temperature to perform the FCG evaluation, the staff finds this issue closed.

3.2 Pressurizer Surge Line Inspection Program

The program elements of the proposed Pressurizer Surge Line Inspection Program are evaluated in the following sections.

3.2.1 Scope of Program

The pressurizer surge line of Palo Verde, Units 1, 2, and 3, includes 12-inch nominal pipe size, schedule 160, ASME SA-376 or SA-312 Grade TP304 pipe and SA-403 Grade WP304 elbows. Table 3 of the licensee's request dated July 26, 2023, lists the pressurizer surge line weld and elbow locations that will be examined in the Pressurizer Surge Line Inspection Program. Volumetric examination will be performed on each inspection location once per 10 years in accordance with the Palo Verde inservice inspection (ISI) program and ASME Code, Section XI. The licensee indicated that the aging effect managed with these inspections is cracking due to EAF. The licensee also explained that volumetric examination was conducted on the weld and elbow locations and there were no detectable flaws.

The NRC staff finds that the "Scope of Program" program element is acceptable because (1) the "Scope of the Program" element clearly identifies cracking due to EAF in the pressurizer surge line welds and elbows as the aging effect and associated components for aging management and (2) the program element is consistent with the guidance in section A.1.2.3.1 of the Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants, Revision 2, December 2010 (SRP-LR) (ML103490036).

3.2.2 Preventive Actions

The licensee stated that there are no specific preventive actions under the program to prevent the effect of aging. The NRC staff finds that the “Preventive Actions” program element is acceptable because (1) a condition monitoring program such as the licensee’s Pressurizer Surge Line Inspection Program may not rely on preventive actions, and thus, the information for preventive actions need not be provided, as discussed in SRP-LR, section A.1.2.3.2, and (2) the licensee’s program relies on periodic inspections in conjunction with the flaw tolerance analysis for aging management rather than preventive actions.

3.2.3 Parameters Monitored or Inspected

Volumetric examinations will be performed on the pressurizer surge line welds and elbows, as described in Table 3 of the licensee’s request dated July 26, 2023. The volumetric examination will be conducted in accordance with the examination provisions of ASME Code, Section XI.

The NRC staff finds that the “Parameter(s) Monitored or Inspected” program element is acceptable because (1) the periodic volumetric inspections in accordance with the examination provisions of ASME Code are sufficient to detect and monitor cracks in the pressurizer surge line and (2) relevant inspection results, including crack sizes, are evaluated to perform corrective actions as needed (e.g., repair or replacement of affected welds), consistent with the guidance in SRP-LR section A.1.2.3.3.

3.2.4 Detection of Aging Effects

The aging effect managed for the pressurizer surge line welds and elbows is cracking due to EAF. The aging management will be accomplished by performing periodic volumetric examinations. The frequency of the volumetric examinations (i.e., once per 10 years) is based on the flaw tolerance evaluation in accordance with ASME Code, Section XI, appendix L.

The flaw tolerance evaluation results confirm that the conservatively determined fatigue crack growth of a postulated flaw takes more than 10 years to affect the structural integrity of the pressurizer surge line welds and elbows. The most limiting operating time period before a postulated flaw grows to the maximum allowable flaw size is 13 years, which is greater than the licensee-proposed 10-year time period between the planned inspections. Therefore, the NRC staff finds that the flaw tolerance evaluation results support that the inspection frequency is sufficient to manage cracking due to EAF for the pressurizer surge line.

The NRC staff finds that the “Detection of Aging Effects” program element is acceptable because (1) the volumetric examinations are sufficient to detect cracking due to EAF in the pressurizer surge line, (2) the program uses an adequate inspection frequency (once per 10 years) in accordance with the provisions for flaw tolerance evaluation in ASME Code, Section XI, appendix L, (3) the inspection frequency is also supported by the examination results of the licensee that there are no detectable flaws in the pressurizer surge line welds and elbows and (4) the program element specifically identifies cracking due to EAF as the aging effect to be managed and how the aging effect will be detected and managed (i.e., detection of aging effect through periodic inspections based on the flaw tolerance evaluation), consistent with the guidance in SRP-LR section A.1.2.3.4.

3.2.5 Monitoring and Trending

The licensee explained that the pressurizer surge line is subject to thermal fatigue degradation and risk-informed inspections in accordance with ASME Code Case N-716-1, “Alternative Piping Classification and Examination Requirements, Section XI, Division 1.” In addition to the periodic volumetric examinations discussed above, subparagraph 6(a)(2) of Code Case N-716-1 specifies successive inspection requirements. If detected flaws are accepted for continued service by analytical evaluation of flaws in accordance with ASME Code, Section XI, IWB-3132.3, the areas containing flaws are required to perform successive inspections. The analytical evaluation of flaws follows the provisions of ASME Code Section XI, IWB-3600. The licensee also indicated that, if a flaw is identified in the pressurizer surge line, it will evaluate the flaw to assess the effect of EAF and to determine impacts on the EAF analysis.

The NRC staff finds that the “Monitoring and Trending” program element is acceptable because of the following: (1) the periodic volumetric examinations and their frequency (once per 10 years base on the flaw tolerance analysis) are adequate to monitor and trend cracking due to EAF in the pressurizer surge line; (2) detected flaws are evaluated against the acceptance standards specified in ASME Code, Section XI, IWB-3500; (3) if detected flaws are accepted for continued service based on analytical evaluation of flaws, successive inspections are conducted to ensure the integrity of the piping line; (4) if flaws are identified during examinations, the examination results are also evaluated to assess the impacts of the degradation on the licensee’s EAF analysis for Class 1 components and piping; and (5) the licensee’s approach is consistent with the guidance in SRP-LR section A.1.2.3.5 that the program element includes an evaluation of the results against the acceptance criteria and a prediction regarding the rate of degradation in order to ensure that the next scheduled inspection will occur before a loss of the component’s intended function.

3.2.6 Acceptance Criteria

In the evaluation of detected flaws, the licensee’s inspection program uses the acceptance standards specified in ASME Code Section XI, IWB-3500 for the welds and Section III, NB-2500 for the elbows.

The NRC staff finds that the “Acceptance Criteria” program element is acceptable because (1) the periodic volumetric examinations evaluate relevant indications of degradation in accordance with the acceptance standards specified in ASME Code, (2) the acceptance standards of the ASME Code are sufficient to evaluate relevant indications and to initiate corrective actions as needed, consistent with the current licensing basis, and (3) the licensee’s approach is consistent with the guidance in SRP-LR section A.1.2.3.6 that the current licensing basis acceptance criteria such as NRC-endorsed codes and standards can be used.

3.2.7 Corrective Actions

The licensee will generate condition reports in accordance with the Palo Verde corrective action program for flaws that exceed the acceptance criteria. Components with examination results that do not meet the acceptance criteria are subject to acceptance by analytical evaluation per ASME Code Section XI, appendices A and C or acceptance by repair or replacement in accordance with IWA-4000.

The NRC staff finds that the “Corrective Actions” program element is acceptable because (1) the flaws, which do not meet the acceptance criteria, will be repaired, replaced or analytically

evaluated for continued service in accordance with the ASME Code provisions, consistent with the current licensing basis, and (2) the licensee's approach is consistent with the guidance in SRP-LR section A.1.2.3.7 that, if corrective actions permit analysis without repair or replacement, the analysis should ensure that the intended functions of the components are maintained, consistent with the current licensing basis.

3.2.8 Confirmation Process

As discussed above, if degradation is identified in the pressurizer surge line, the licensee will perform an engineering evaluation to determine if the surge lines are acceptable for continued service or if repair or replacement is required. The licensee also stated that the engineering evaluation will include probable cause, the extent of degradation, the nature and frequency of additional examinations, and whether repair or replacement is required. The licensee further indicated that it performs repair and replacement activities in accordance with the requirements of ASME Code, Section XI, IWA-4000, as described in the Palo Verde procedure for the repair and replacement.

The NRC staff finds that the "Confirmation Process" program element is acceptable because of the following: (1) if degradation is identified in the pressurizer surge line, the licensee will determine the cause of degradation, the extent of degradation and additional examination, and the need for repair or replacement in accordance with the ASME Code requirements and licensee's procedure for implementing and confirming corrective actions; and (2) the licensee's approach is consistent with the guidance in SRP-LR section A.1.2.3.8 that, when corrective actions are necessary, there should be follow-up activities to confirm that the corrective actions have been completed and a root cause determination was performed. The licensee's administrative control process for inspections and corrective actions is further evaluated below.

3.2.9 Administrative Controls

The licensee stated that the Palo Verde ISI program will document the EAF inspection requirements for the pressurizer surge line under the ASME Code Section XI, ISI program. The applicant also explained that the site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with the requirements of Appendix B of 10 CFR Part 50, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," and will continue to be applicable for the period of extended operation. The utilized administrative control procedures include the condition reporting process and ASME Code repair/replacement process.

The NRC staff finds that the "Administrative Controls" program element, which complies with the requirements of 10 CFR Part 50, Appendix B, is consistent with the guidance in SRP-LR section A.1.2.3.9 and, therefore, is acceptable.

3.2.10 Operating Experience

The licensee indicated that the pressurizer surge line welds and sentinel (limiting) elbow base metal were inspected during the most recent refueling outage of each unit (Unit 1, spring 2022; Unit 3, fall 2022; and Unit 2, spring 2023 refueling outages). The licensee also confirmed that no reportable flaws were identified in any of the examinations. The licensee further explained that, even though no incidents of thermal fatigue cracking have been observed in the pressurizer surge line piping of U.S. PWR plants, the effects of EAF are recognized as potential contributors to aging-induced degradation. Accordingly, the licensee proposed the use of the Pressurizer

Surge Line Inspection Program to manage the effects of EAF for the pressurizer surge line. As discussed above, the program includes the evaluation of inspection results and the evaluation of the effects of EAF on Class 1 reactor coolant pressure boundary piping and components based on the inspection results.

In addition, the licensee explained that corrective actions, confirmation process and administrative controls for license renewal are in accordance with the Palo Verde Quality Assurance Program pursuant to 10 CFR Part 50, Appendix B, which governs the quality assurance related to the structures, systems, and components subject to an aging management review.

The NRC staff finds that the “Operating Experience” program element and associated discussions are acceptable because (1) the inspections on the pressurizer surge line welds and elbows at Palo Verde, Units 1, 2 and 3, did not reveal any indications of cracking, which is consistent with the industry operating experience regarding the absence of thermal fatigue cracking in pressurizer surge lines, and (2) the licensee will continue to evaluate plant-specific and industry operating experience related to cracking due to EAF in the pressurizer surge line for aging management, consistent with the guidance in SRP-LR section A.1.2.3.10.

4.0 CONCLUSIONS

As set forth above, the NRC staff determined that the licensee-proposed Pressurizer Surge Line Inspection Program and the associated flaw tolerance evaluation are acceptable to manage cracking due to EAF for the pressurizer surge line at Palo Verde, Units 1, 2 and 3 by using the periodic inspections (once per 10 years) for the period of extended operation. Therefore, the NRC staff approves the use of the proposed Pressurizer Surge Line Inspection Program for the period of extended operation.

Principal Contributors: S. Min, NRR
K. Hsu, NRR

Date: July 24, 2024

SUBJECT: PALO VERDE NUCLEAR GENERATING STATION, UNITS 1, 2, AND 3 – PRESSURIZER SURGE LINE INSPECTION PROGRAM (EPID L-2023-LRO-0052) DATED JULY 24, 2024

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